

Approximate versus Linguistic Representation in Fuzzy-UCS

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Motivation

- **Fuzzy-UCS (Orriols-Puig, Casillas & Bernadó-Mansilla, 2008)**

- First Michigan-style Learning Fuzzy Classifier System
- Evolves a population of linguistic fuzzy rules

IF x_1 is small and x_2 is medium or large THEN class₁

- **May the linguistic rep. limit the expressiveness of Fuzzy-UCS?**

- Rules share the same semantics
- Need of overlapping rules to predict curved boundaries

- **To gain expressivity:**

- Approximate representation. Let each variable define its own fuzzy set

IF x_1 is  and x_2 is  THEN class₁

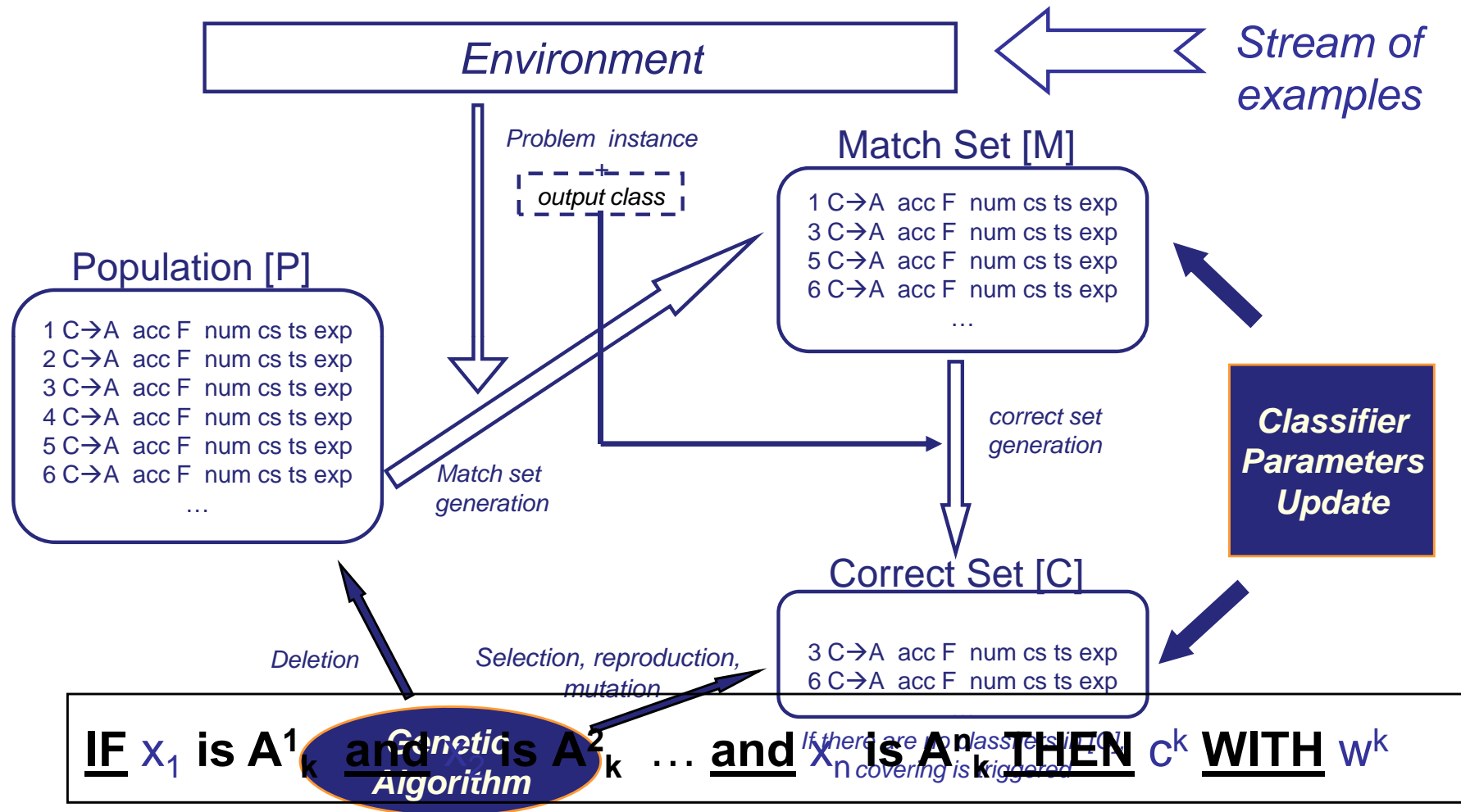
- **Purpose of the present work**

- Define an approximate rep. for Fuzzy-UCS
- Compare the approximate rep. with the linguistic rep.

Outline

- 1. Description of Fuzzy-UCS**
- 2. Approximate Representation**
- 3. Experimental Methodology**
- 4. Results**
- 5. Conclusions and Further Work**

Description of Fuzzy-UCS



Description of Fuzzy-UCS

- **Weighted average inference (wavg)**
 - All rules vote for the class they predict according to: $w^k \cdot u_A^k(e)$
 - The most voted class is selected as the output

- **Action winner inference (awin)**
 - Keep the rules that maximize $w^k \cdot u_A^k(e)$ for, at least, one training example
 - In test, predict the class of the rule that maximizes $w^k \cdot u_A^k(e)$


- **Most numerous and fittest rules inference (nfit)**
 - Keep the rules that maximize $w^k \cdot u_A^k(e) \cdot \text{num}^k$ for, at least, one training example
 - Vote as weighted average

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Approximate Representation

- Each variable is represented by an independent fuzzy set

IF x_1 is  and x_2 is  ... and x_n is  THEN c^k WITH w^k

- All the genetic operators are redefined as follows
 - Covering
 - Crossover
 - Mutation

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Experimental Methodology

- **Comparison of**
 - Linguistic Fuzzy-UCS with 5 linguistic terms per variable with
 - **Weighted average inference**
 - **Action winner inference**
 - **Most numerous and fittest rule inference**
 - Approximate Fuzzy-UCS
 - **Action winner inference**
 - C4.5
 - **As a baseline result**
- **20 real-world problems from the UCI repository**

Experimental Methodology

□ Evaluation metrics (10-fold cross validation)

- Training accuracy
- Test accuracy
- Rule set size

□ Statistical comparison

- Friedman test
- Nemenyi test

□ Systems configuration

$N=6400$, $F_0 = 0.99$, $v = 10$, $\{\theta_{GA}, \theta_{del}, \theta_{sub}\} = 50$, $Pc = 0.8$, $Pm = 0.04$, and $P\# = 0.6$

Linguistic Fuzzy-UCS: 5 linguistic terms per variable

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Results

□ Comparison of the training accuracy

		Fuzzy-UCS			Fuzzy-UCSa	C4.5
		wavg	awin	nfit		
train	Rank	3.35	4.20	3.10	1.75	2.60
	Pos	4	5	3	1	2

- Friedman rejected the null hypothesis that all the learners performed the same on average
- Nemenyi test: $CD_{0.10} = 1.23$
- Approximate Fuzzy-UCS fits the training instances more accurately than linguistic Fuzzy-UCS

Results

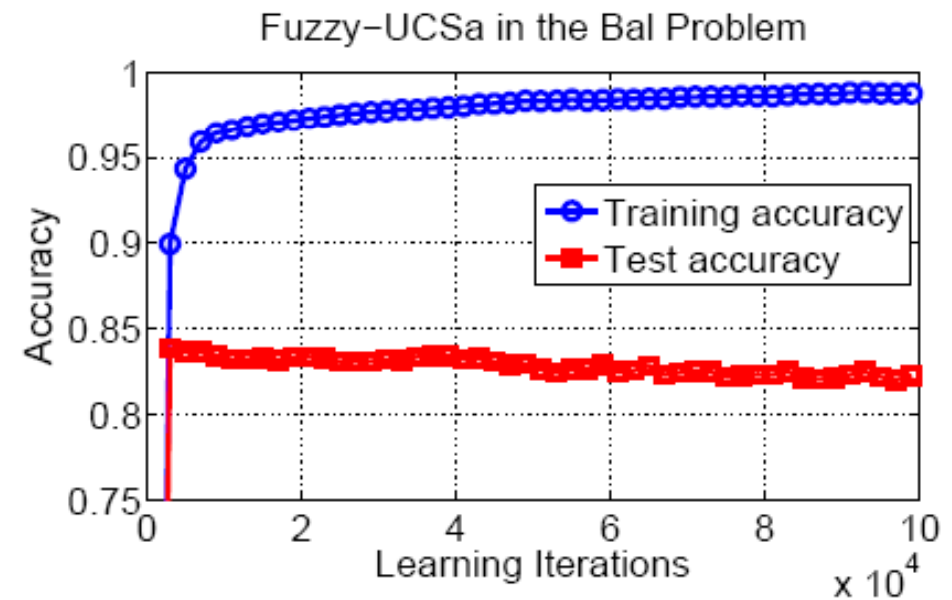
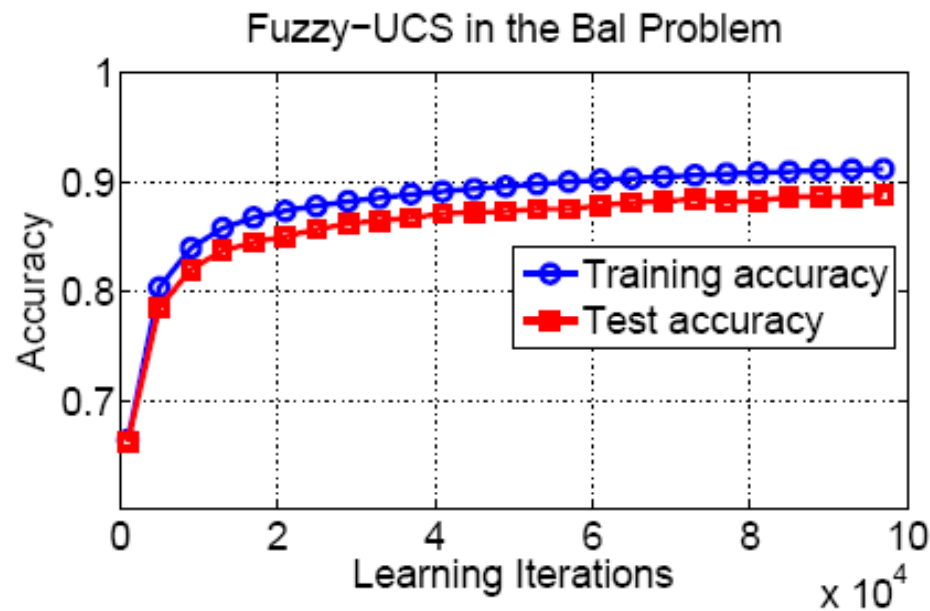
- Does this behavior appears in test?

		Fuzzy-UCS			Fuzzy-UCSa	C4.5
		wavg	awin	nfit		
test	<i>Rank</i>	2.05	3.25	3.80	2.95	2.95
	<i>Pos</i>	1	4	5	2.5	2.5

- **Friedman** rejected the null hypothesis that all the learners performed the same on average
- **Nemenyi test**: $CD_{0.10} = 1.23$
- The best learners of the comparison were:
 - **Fuzzy-UCS wavg, awin, approximate Fuzzy-UCS and C4.5**
- Why approximate Fuzzy-UCS does not improve linguistic Fuzzy-UCS?

Results

- We observed that approximate Fuzzy-UCS may overfit the training instances in some specific domains



Results

□ Comparison in terms of interpretability

		Fuzzy-UCS			Fuzzy-UCSa
		wavg	awin	nfit	
size	<i>Rank</i>	3.95	2.05	1.00	3.00
	<i>Pos</i>	4	2	1	3

- **Friedman** rejected the null hypothesis that all the learners performed the same on average
- **Nemenyi test**: $CD_{0.10} = 1.23$
- Fuzzy-UCS with nfit and awin evolve the most reduced rule sets
- Still, Fuzzy-UCSa evolves large populations
- Approximate representation is less legible than linguistic rep.

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Conclusions and Further Work

□ **Conclusions**

- We evidenced the advantages and disadvantages of linguistic and approximate representation
- The approximate representation enables Fuzzy-UCS to fit the training instances more accurately
- But this improvement was not present in test
 - **Overfitting in some cases**

□ **Further work**

- Extend the comparison to two other representations
 - **Only permit a linguistic term per variable**
 - **Hierarchic linguistic terms**

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